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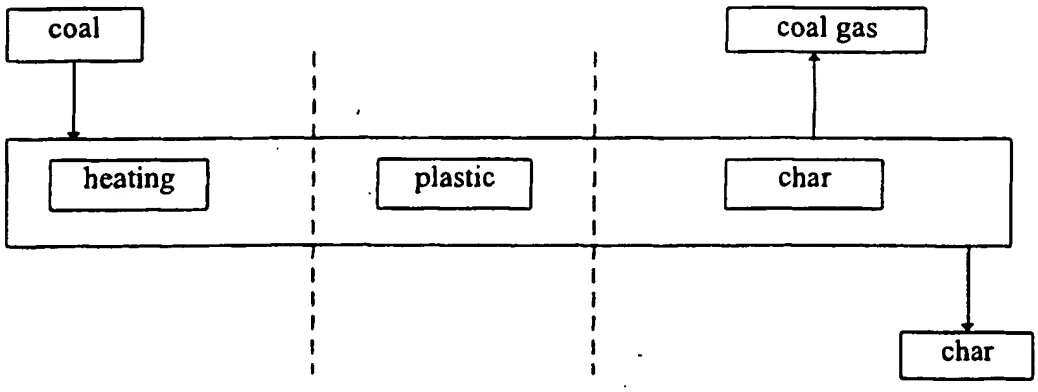
(54) Title: PROCESS AND APPARATUS FOR MAKING CHAR FROM COKING COAL



(57) Abstract: The invention relates to a process for making char or a type of semicoke from coking coal, the process comprising a first phase of heating the coal, a second phase of heating in which the coal becomes plastic, loses volatiles and becomes brittle, and a third phase in which the coal further loses volatiles and becomes char or a type of semicoke. According to the invention, the first phase takes place in a first housing, the second phase takes place in a second housing, and the third phase takes place in a third housing. The invention also relates to an apparatus for making char or a type of semicoke.

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PROCESS AND APPARATUS FOR MAKING CHAR FROM COKING COAL

The invention relates to a process for making char or a type of semicoke from coking coal, the process comprising a first phase of heating the coal, a second phase of heating in which the coal becomes plastic, loses volatiles and becomes brittle, and a third phase in which the coal further loses volatiles and becomes char or a type of semicoke. The invention also relates to an apparatus for making char or semicoke from coking coal.

A process for making char from coking coal, making use of an apparatus for making char from coal having a screw in a housing and heating means for heating the coal, is known. Solid coal is transported through the apparatus or reactor by rotating the screw, while at the same time the coal is heated by the heating means. For good transport the solid coal should be "free flowing". However, when the coal reaches a certain temperature, the coal weakens and a plastic phase is formed; the plastic coal is not free flowing anymore. At a sufficient temperature and when most volatiles are volatilised from the plastic phase, the plastic phase becomes brittle. It breaks off in lumps, and proceeds to the end of the screw as a free flowing char. Char can for instance be used as an ingredient for making iron in the iron making industry or as an ingredient for making non-ferro metals, or other reduction processes, or as (clean) fuel.

The coal can flow more or less freely during the first phase, when it is heated up, and during the third phase or char phase. In these phases, the coal or char should not be sticky. However, during the second or plastic phase the coal is not free flowing and the transport of the coal is governed by its plasticity and the resulting sticky behaviour. The plasticity can be determined by the well-known Gieseler plasticity test, ASTM D 2639. Due to the difference between the high stickiness in the plastic phase and the non-stickiness in the first and third phase, there exists a substantial difference in residence time and voidage or space utilisation in the different zones of the apparatus; in the first and third phase a high voidage exist. High voidage will cause a low heated surface to transport heat to the coal to be processed.

It is an object of the invention to provide a process for making char from coal which is less residence time consuming than the known process.

It is another object of the invention to provide a process for making char from coal in which the voidage can be at least partly overcome.

It is still another object of the invention to provide a process for making char from coal, which is cheaper than the known process.

It is yet another object of the invention to provide an apparatus for making char from coal, using a screw, which has a better mechanical performance than the known apparatus.

According to a first aspect of the invention at least one of the above objects is reached with a process for making char from coking coal, the process comprising a first phase of heating the coal, a second phase of heating in which the coal becomes plastic, loses volatiles and becomes brittle, and a third phase in which the coal further loses volatiles and becomes char, wherein the first phase takes place in a first housing, the second phase takes place in a second housing, and the third phase takes place in a third housing, the three housings being separate from each other.

Due to the invention the three phases of the process now are each performed in a separate housing, and each phase can be optimised in accordance with its own needs. For instance the coal in the first housing can be transported with a velocity that differs from the velocity in the second housing. In this way the voidage in the coal in the first housing can be lower, and the first housing can be smaller as compared to the part of the housing in the known apparatus for heating the coal.

Preferably, a first heating means is used for the first phase and a second heating means is used for the second phase, and more preferred the first and second heating means are separate heating means. Using a first heating means for the first housing and a second heating means for the second housing which are separate from each other has the advantage that the heating for the first phase and the heating for the second phase can both be optimised.

Preferably also during the third phase the coal or char is heated by a third heating means. The making of char during the third phase can be optimised by controlling the heating during the third phase.

According to a preferred embodiment in the second housing a screw is used as a transport means for transporting coal, preferably a double screw. Using a screw will not only result in transporting the sticky coal in the second phase, but also in mixing the coal, resulting in an improved heat transfer. Using a double screw will result in a better heat transfer efficiency and control.

Preferably in the first housing a transport means is used for transporting coal, more preferably a screw. Though it would be possible to transport the coal through the first housing by means of gravity, to control the transport a transport means is necessary. A screw can be used for a better heat transfer to the coal.

Preferably in the third housing a transport means is used for transporting coal or char, more preferably a screw. In the third housing the coal or char can be transported by means of gravity. However, a better controlled transport is reached by using a transport means. If heat is to be transferred as well, a screw is a preferred transport means.

According to a preferred embodiment of the process, during the first phase the coal is heated to a temperature of 300 to 500 °C, preferably to a temperature of 300 to 400 °C. Preferably, the end temperature of the first phase is 1 - 100 °C below the start of the Gieseler plasticity temperature range. At these temperatures, the coal is not yet plastic. The end temperature of the first phase thus depends on the type of coal used.

Preferably, during the second phase the coal is heated to a temperature of 300 to 600 °C, more preferably to a temperature of 400 to 500 °C. Preferably, the end temperature of the second phase is 1 - 50 °C above the end of the Gieseler plasticity temperature range. At these temperatures, the coal will become sufficiently plastic. Thus, the end temperature of the second phase also has to be chosen depending in the type of coal used.

Preferably, during the third phase the coal or char is heated to an end temperature of 400 to 700° C. Of course this end temperature also depends on the type of coal used. For most types of coal, the end temperature is approximately 600 °C. At this temperature, the volatile matter content of the char is right for most applications.

According to a preferred embodiment of the process, the screw in the second housing is rotated approximately three to twenty times as fast as a screw in the first housing. In this way the voidage in the first and third housing is as low as possible.

According to a second aspect of the invention, there is provided an apparatus for making char from coking coal, comprising a screw in a housing and heating means for heating the coal, wherein the apparatus comprises a first housing with a first heating means for heating the coal to a predetermined temperature as a first phase, a second housing with the screw and a second heating means for transporting, mixing and

heating the coal such that it becomes plastic, loses volatiles and becomes brittle as a second phase, and a third housing for the coal to further lose volatiles and become char as a third phase.

This apparatus can be used for performing the process according to the first aspect of the invention, due to the presence of three housings for the three phases of the process, and the heating means.

Preferably, the screw in the second housing is provided as a double screw. A double screw gives a very good mixing of the coal.

According to a preferred embodiment, the first housing comprises a first transport means for transporting the coal through the housing, preferably a screw. To control the transport of coal through the first housing, a transport means is necessary. A screw can be used for a better heat transfer to the coal, by mixing the coal.

Preferably the third housing comprises a third heating means and/or a third transport means for heating and/or transporting the coal or char through the third housing. Though the coal or char can be transported through the third housing by means of gravity, a transport means gives a better control. Further heating means for the third housing are necessary if the coal or char from the second housing needs to be heated to get a better quality char.

According to a preferred embodiment, the first and/or third transport means is a screw. By using a screw, the coal or char is mixed and a better heat transfer is reached.

Preferably, each of the screws is rotatable at an adjustable speed. By using screws that are rotated at an adjustable speed, the coal can be rotated at a speed at which there is little or no voidage during the first and third phase. Moreover, because separate screws are used, each in its own housing, each screw will be shorter compared to the one screw in the known apparatus, so the mechanical stability of the apparatus according to the invention will be higher.

According to a preferred embodiment, at least the screw in the second housing has an hollow shaft. A heating medium can now pass through the second screw, which helps the heating of the sticky coal in the second phase. The second screw and second housing can thus be shorter, and the apparatus be more compact and cheaper. The same holds for a hollow shaft for the first or third screw.

Preferably between the first and second housing and/or between the second and third housing a passageway is present, more preferably a passageway which is essentially gastight. A passageway between the first and second housing and/or between the second and third housing will lead to a kind of separation of the gasses produced by the coal during the three phases of the process. Preferably the passageways are substantially gastight, so the watery gasses produced during the first phase are separated from the volatiles during the second phase, which contain hydrocarbons. It could be worthwhile to separate the gasses produced during the second and third phase, for instance because they have a different heating power, so a substantially gastight passageway between the second and third housing could be useful.

A preferred embodiment of the apparatus comprises an inlet device for introducing coal in a first housing with a first screw and first heating means for heating the coal to a predetermined temperature, the first screw being provided for mixing the coal and transporting the heated coal into a second housing with a second screw and second heating means for heating the coal until it is plastic and loses volatiles, the second screw being provided for mixing the plastic coal, heating the plastic coal sufficiently using the second heating means to turn it brittle and solid without any stickiness and transporting the thus made char into a third housing with a third screw and third heating means so as to make the coal further lose volatiles, the third screw being provided for mixing the char and heating it up to a prescribed temperature using the third heating means, and transporting it to the end of the housing and delivering it as char.

This preferred embodiment has a very efficient design. The voidage in the various screws can for instance be controlled by decreasing or increasing the speed of the screws.

Using this apparatus, the achievable end temperature for the char can be higher than with one long screw, due to better mechanical stability of three screws in series compared to one long screw.

Preferably, each screw is provided as a double screw. A double screw gives a very good mixing of the coal.

The invention will be described referring to the accompanying drawing.

Fig. 1 shows the apparatus according to the state of the art, schematically.

Fig. 2 shows a preferred embodiment of the apparatus according to the invention as compared to the apparatus of the state of the art.

Fig. 3 shows two different embodiments of the apparatus according to the invention, as compared to the apparatus of the state of the art.

Fig. 1 shows in a schematic way an apparatus according to the state of the art, having a housing with a screw inside (not shown). Coal is entered into the housing at the inlet, and transported by the screw. At the outlet, char leaves the housing. The apparatus can be divided into three zones, respectively a first or heating zone, a second or plastic zone, and a third or char zone. In both the heating and char zone, coal gas is formed which leaves the apparatus via a separate outlet. The plastic zone is indicated as being limited by the two interrupted lines.

Fig. 2 shows the known apparatus in its upper half, and in the lower half an embodiment of the apparatus according to the invention. As shown, in the apparatus according to the invention each of the heating, plastic and char zones now has its own housing with its own screw (not shown). These housing are called the first, second and third housing, respectively. Due to this concept, each of the screws in each of the housings can be rotated at optimal speed, so the voidage in the heating and char zone can be minimised, and the total reaction time for the forming of char in the apparatus can be kept as low as possible.

Fig. 3 shows that for one type of coal the temperature limits of the plastic zone can be as indicated by the interrupted lines, while for another type of coal the temperature limits of the plastic zone can be indicated by the dotted line. In Fig. 3, the upper embodiment again is the known apparatus. The middle apparatus is the same as shown in Fig. 2, which is suited for the coal type with the plastic limits as interrupted lines. The lower embodiment would be an apparatus which is suited for the coal type with plastic limits indicated by the dotted lines.

The coal should enter the second housing for the plastic zone preferably at a temperature which is just below the lower temperature limit of the plastic zone, so the coal will not be plastic in the first housing for the heating zone.

If a coal type would be used which has a lower temperature limit of the plastic zone which is decreased in comparison with the lower temperature limit of the coal for which the apparatus has been build, the first housing and the first screw for the heating

zone should be shorter in case the heating rate (the amount of energy supplied per second) in the heating zone is constant. This is because the end temperature of the coal in the first housing must be lower. However, it would also be possible to maintain the length of the housing and screw, and to reduce the heating rate in the heating zone. This reduced heating rate can be achieved by either decreasing the heating temperature or the flow of the medium with which the housing is heated while keeping the same screw speed, or by increasing the screw speed while keeping the heating rate of the first housing the same.

If a coal type would be used which has a lower temperature limit of the plastic zone which is increased in comparison with the lower temperature limit of the coal for which the apparatus has been build, the first housing and the first screw for the heating zone should be longer in case the heating rate in the heating zone is constant. This is because the end temperature of the coal in the first housing must be higher. However, it would also be possible to maintain the length of the housing and the screw, if it is possible to increase the heating rate in the heating zone. This could either be achieved by increasing the heating temperature or the flow of the medium with which the housing is heated while keeping the same screw speed, or by decreasing the screw speed while keeping the heating rate of the first housing the same.

It will be clear from the above that one apparatus can be used for different types of coal with different lower temperature limits for the plastic zone, by changing the heating rate for the first housing through process parameters like the temperature of the heating medium and/or the residence time or screw speed in the first housing.

The same holds, mutatis mutandis, for the second and third housing with respect to the lower and upper temperature limits for the plastic zone, and the end temperature for the char making. Here, too, the process parameters can be used to change the heating rate, so the lengths of the second and third housing can remain the same and one apparatus can be used for different types of coal.

During the plastic zone, the heat transfer controls the reaction and especially the heat load will govern the residence time. The screw speed is especially important for the mixing and the heat transfer to the plastic phase. As long as the temperature is below the upper Gieseler plasticity temperature the coal remains sticky, is resident at the same

spot and will not be transported. As soon as the temperature is high enough, the coal turns brittle, and breaks off. The coal flows again (to the third screw).

The screws used can be single (transportation) screws, but preferably are double screws which have better mixing properties.

During use of the apparatus, the speed of the screws in the heating and char zone can be approximately 15 % of the speed of the screw in the plastic zone. For this reason, the screws in the heating and char zone can be short, and the total processing time of the coal can be short. In the heating zone, the coal is heated to a temperature of 300 to 500 °C, depending on the type of coal used. In the plastic zone, the coal reaches a temperature of 400 to 600 °C. In the char zone, the char gets a temperature of approximately 600 ° C depending on the target value of the volatile matter of the char.

The apparatus also has the great advantage that three screws are used instead of one long screw. A long screw in a long housing makes the apparatus mechanically less stable. Moreover, for the different zones now different materials for screw and housing can be used, suited for the circumstances in that zone.

CLAIMS

1. Process for making char or a type of semicoke from coking coal, the process comprising a first phase of heating the coal, a second phase of heating in which the coal becomes plastic, loses volatiles and becomes brittle, and a third phase in which the coal further loses volatiles and becomes char or a type of semicoke, characterised in that the first phase takes place in a first housing, the second phase takes place in a second housing, and the third phase takes place in a third housing, the three housings being separate from each other.

2. Process according to claim 1, characterised in that a first heating means is used for the first phase and a second heating means is used for the second phase, and preferably the first and second heating means are separate heating means.

3. Process according to claim 1 or 2, characterised in that during the third phase the coal or char is heated by a third heating means.

4. Process according to claim 1, 2 or 3, characterised in that in the second housing a screw is used as a transport means for transporting coal, preferably a double screw.

5. Process according to any of the preceding claims, characterised in that in the first housing a transport means is used for transporting coal, preferably a screw.

6. Process according to any of the preceding claims, characterised in that in the third housing a transport means is used for transporting coal or char, preferably a screw.

7. Process according to any of the preceding claims, characterised in that during the first phase the coal is heated to a temperature of 300 to 500 °C, preferably to a temperature of 300 to 400 °C.

8. Process according to any of the preceding claims, characterised in that during the second phase the coal is heated to a temperature of 300 to 600 °C, preferably to a temperature of 400 to 500 °C.

9. Process according to any of the preceding claims, characterised in that during the third phase the coal or char or a type of semicoke is heated to an end temperature of 400 to 700° C.

10. Process according to any of the preceding claims 4-9, characterised in that the screw in the second housing is rotated approximately three to twenty times as fast as a screw in the first housing.

11. Apparatus for making char or a type of semicoke from coking coal, comprising a screw in a housing and heating means for heating the coal, characterised in that the apparatus comprises a first housing with a first heating means for heating the coal to a predetermined temperature as a first phase, a second housing with the screw and a second heating means for transporting, mixing and heating the coal such that it becomes plastic, loses volatiles and becomes brittle as a second phase, and a third housing for the coal to further lose volatiles and become char or a type of semicoke as a third phase.

12. Apparatus according to any of the preceding claims, characterised in that the screw in the second housing is provided as a double screw.

13. Apparatus according to claim 11 or 12, characterised in that the first housing comprises a first transport means for transporting the coal through the housing, preferably a screw.

14. Apparatus according to claim 11, 12 or 13, characterised in that the third housing comprises a third heating means and/or a third transport means for heating and/or transporting the coal or char or a type of semicoke through the third housing.

15. Apparatus according to claim 13 or 14, characterised in that the first and/or third transport means is a screw.

16. Apparatus according to any of the claims 11-15, characterised in that each of the screws is rotatable at an adjustable speed.

17. Apparatus according to any of the claims 11-16, characterised in that at least the screw in the second housing has an hollow shaft.

18. Apparatus according to any of the claims 11-17, characterised in that between the first and second housing and/or between the second and third housing a passageway is present, preferably a passageway which is essentially gastight.

19. Apparatus for making char according to the process of claims 1-10, characterised in that the apparatus comprises an inlet device for introducing coal in a first housing with a first screw and first heating means for heating the coal to a predetermined temperature, the first screw being provided for mixing the coal and transporting the heated coal into a second housing with a second screw and second heating means for heating the coal until it is plastic and loses volatiles, the second screw being provided for mixing the coal, heating the plastic coal sufficiently using the second heating means to turn it brittle and solid without stickiness and transporting the thus made char or a type of semicoke into a third housing with a third screw and third heating means so as to make the coal or semicoke further lose volatiles, the third transport means being provided for mixing the char or semicoke and heating it up to a prescribed temperature using the third heating means, and transporting it to the end of the housing and delivering it as char or semicoke.

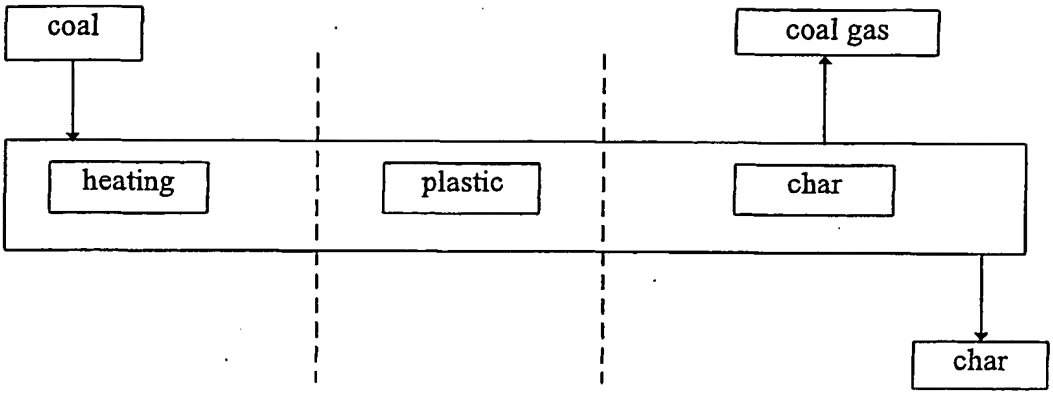


FIGURE 1

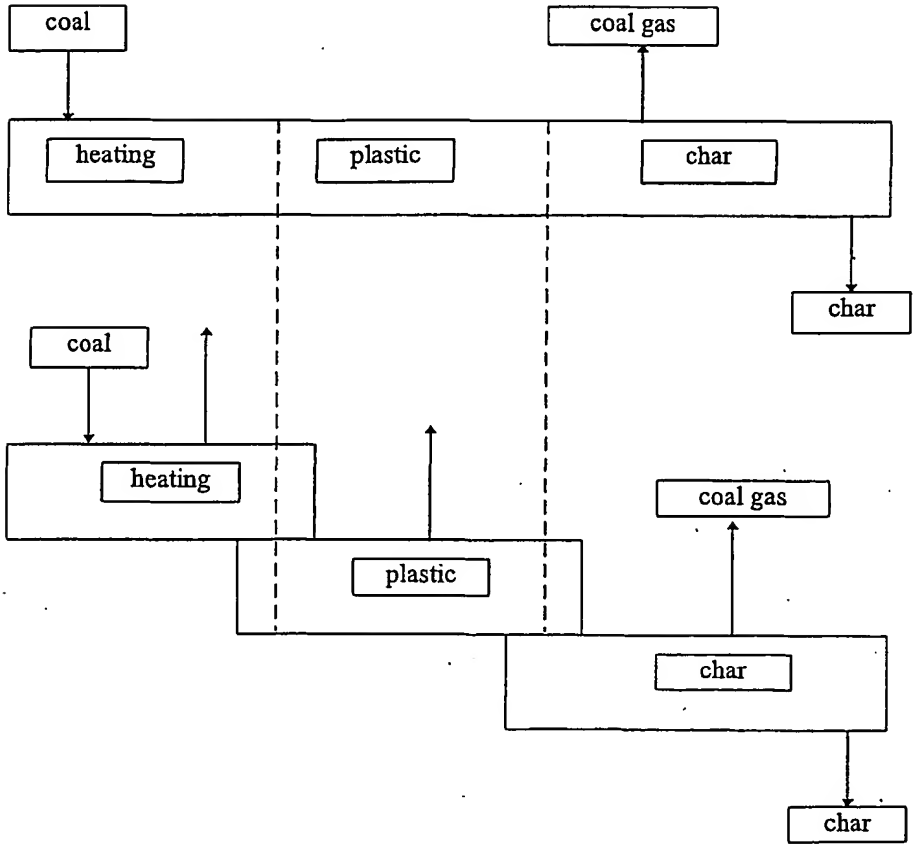
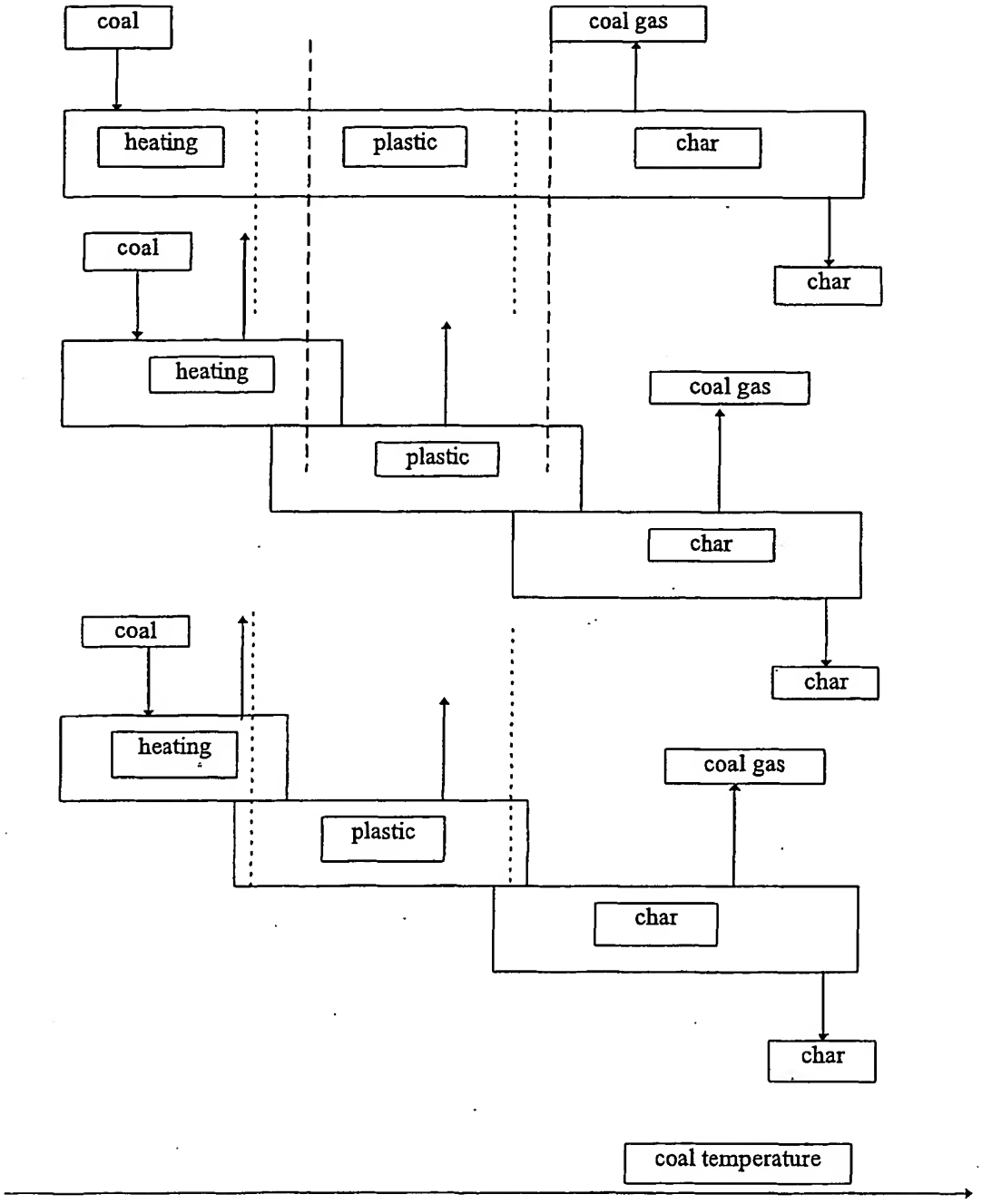


FIGURE 2


coal
coal gas
heating
plastic
char
coal
char
heating
coal gas
plastic
char
coal
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heating
coal gas
plastic
char
char
coal temperature

FIGURE 3

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